Missouri's Muskie Management Plan

2008-2017

Missouri Department of Conservation

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EXECUTIVE SUMMARY

". . . every angler who has ever tossed a muskie plug will come away impressed. He may become an addict. He may become bored. He may become exhausted or uncontrollably ecstatic. He may wish he'd never heard of a muskie. Or he may regret not having met such a fish earlier in life.

. . . The muskie has a magnetism possessed by few other sports critters. . . I know of no fisherman, who, once touched by the fish's magic, has ever forgotten the experience."

Ron Schara, Muskie Mania, 1977

Missouri's muskellunge (muskie) program was initiated at Pomme de Terre Lake in 1966 to provide Missourians an opportunity to experience muskie magic without having to leave the state, and to provide a trophy fishery with a predator that could prey upon large non-game fishes, such as gizzard shad and redhorse suckers.

Forty years and two plans later, we consider our muskie stocking and management program to be a great success. Each year, anglers report catching muskie weighing 25 to 30 pounds and the Missouri state record stands at 41 pounds, two ounces. The program has grown from just one lake to five lakes that are currently managed for muskie (Table 1, Figure 1). In addition, four other small lakes were stocked and evaluated over the previous 10 years but were removed from the program due to various factors such as habitat quality, muskie mortality, and low angler success.

The mission of the muskie program is to provide special, high-quality angling opportunities in suitable, well-distributed impoundments where more traditional Missouri fisheries will not be adversely affected and may be enhanced. Program objectives are evaluated via annual fyke netting surveys at all muskie lakes and through the Show-Me Muskie Project, a statewide volunteer muskie angler catch reporting system. A key objective is to maintain a density and size structure of muskie populations that results in average annual angler catch rates of one muskie at least 36 inches long every 20 to 40 hours of muskie fishing.

The objectives and strategies outlined in this plan provide a framework to guide Missouri's muskie management and culture efforts. The plan also serves as a tool to help communicate program direction to anglers. The success of Missouri's muskie program to date can be attributed to the interest of Missouri's muskie anglers and their support of the cooperative efforts of hatchery and fisheries management personnel of the Missouri Department of Conservation.

BACKGROUND

The goal of this plan is to provide a framework for developing and maintaining high-quality muskellunge (muskie) fisheries for anglers in Missouri.

The objectives and strategies outlined in this plan will guide Missouri's muskie management and culture efforts. Some of the muskie life history information from our 1995 plan has been included in the appendix.

History of Muskie Stocking and Culture in Missouri

Muskie were first stocked by the Missouri Department of Conservation (MDC) in 1966. Pomme de Terre Lake was stocked with 51,000 small fingerlings (1.5 to 2.0 inches) and approximately 1,500 large fingerlings (7.0 to 15.0 inches) (Table 2). The objective of the program was "to provide Missourians with a trophy fishery utilizing a predator that could prey upon large non-game fishes such as gizzard shad, carp, and various redhorses" (Dent 1986).

From 1981 to 2000, stocked muskie were 10 to 12 inches in length except for four years when smaller fingerlings (approximately eight inches) were stocked. In the early years of the muskie program, Chesapeake and Blind Pony hatcheries were the primary sites for production of large muskie fingerlings in Missouri.

In 1967 and 1968, a total of 249 large fingerlings were reared at the Grand Glaize Hatchery (formerly owned and operated by Ameren/Union Electric) and released into Lake of the Ozarks (55,000 acres). One of these muskie was caught in 1981 at a length of 49.5 inches. It weighed 41 pounds, two ounces and is still the Missouri state record muskie. The record muskie was 14 years old (K. Richards, MDC, personal communication).

Pomme de Terre Lake supported Missouri's only significant muskie fishery until the mid-1980s. Despite a fairly low mean annual stocking density of 0.35 large fingerlings per acre from 1983 through 1990, Pomme de Terre muskie anglers caught one legal muskie (at that time greater than or equal to 30 inches) per 39 hours of effort from 1988 through 1992. This compared very favorably with reported mean catch rates from northern Wisconsin lakes (one per 71 hours) (Hanson 1986) and Minnesota waters (one per 91 hours) (Younk and Cook 1992) at that time.

In 1973, Pony Express Lake (240 acres) was first stocked with muskie. In 1983, the City of Kirksville's new water supply reservoir, Hazel Creek Lake, was stocked with 1,500 muskie fingerlings which originated at the Linesville Fish Culture Station in Pennsylvania and were reared to 10 to 12 inches at Blind Pony Hatchery (Table 3). The lake opened to fishing in 1985

with a 42-inch minimum length limit (MLL) for muskie; the highest in North America at that time.

Early attempts to use Missouri muskie as broodstock for the program date back to the late 1970s when biologists collected eggs from female muskie in Pomme de Terre Lake (R. Dent, MDC, personal communication). In April 1991, biologists were successful in collecting muskie broodstock by using large Wisconsin-style fyke nets in Hazel Creek Lake. Successful fertilization and hatching at Hunnewell Hatchery followed by successful fingerling rearing at Chesapeake and Blind Pony hatcheries launched Missouri into an era of relative independence in muskie fingerling production.

Coordination

To accomplish one of the objectives in the original muskie plan, a Muskellunge Program Coordinator was appointed in 1996 (Neuswanger et al. 1994). Typically, our coordinator will have enough experience with muskie management and muskie fishing that he/she will be able to effectively communicate with muskie anglers and organized groups. This individual coordinates muskie management strategies and communicates statewide muskie information to the public. This coordinator also oversees the Show-Me Muskie Project.

Show-Me Muskie Project

The Show-Me Muskie Project, a statewide volunteer muskie angler catch reporting system, was initiated in 1996 to gather catch data useful to fisheries management biologists and to help evaluate our muskie program. Muskie anglers voluntarily keep records of their fishing results. Achieving our goal of catching a 36-inch or longer muskie every 20 to 40 hours of angling can be documented most efficiently by anglers themselves (Younk and Cook 1992).

We have encouraged muskie anglers to participate in the Show-Me Muskie Project since its inception; we currently have 94 cooperators. Twice each year, letters are provided to all cooperators with updates on muskie culture and management, including annual results from the Show-Me Muskie Project. Table 4 summarizes the results of the Show-Me Muskie Project. Much of the success of this program is due to the support of the Pomme de Terre Chapter of Muskies, Inc. and the participation of chapter members.

Regulations

In January 1996, the statewide MLL for muskie was increased from 30 to 36 inches. The only remaining exception has been at Hazel Creek Lake which has had a 42-inch MLL. Because of the high voluntary release rate of muskie statewide and the relatively low angler effort at Hazel Creek, there is no biological reason to maintain one lake under a different MLL. On March 1,

2008, the 42-inch length limit will be removed and replaced with the statewide length limit. The statewide daily limit is one muskie per day.

MUSKIE LAKE INFORMATION

Lakes Currently Managed for Muskie Fishing (Table 1, Figure 1)

Pomme de Terre Lake

As Missouri's first and largest lake managed for muskie, Pomme de Terre remains the flagship of our muskie program.

From 1995 through 2004, 48,386 muskie (10 to 14 inches) were stocked in Pomme de Terre Lake (Table 2). This resulted in an average annual stocking of 4,839 muskie which was higher than the target of 4,000 per year. During the prior ten-year period, the average annual stocking was 3,450 muskie.

The number of muskie stocked annually from 1995 though 2005 was quite variable, ranging from a low of 2,040 in 2004 to a high of 10,611 in 2000. These fluctuations were tied to the success of annual muskie production at Missouri and/or out-of-state hatcheries. Taking advantage of opportunities to stock more than the annual target of 4,000 muskie, when available, has resulted in some strong year classes which provided quality muskie angling. Throughout this period, the growth rates of muskie and other game fish continued to be very good. An abundance of gizzard shad and other forage species was observed during black bass sampling in 2003 through 2006.

***Terminology tip**: Since 1996, MDC fisheries management biologists have been using the large Wisconsin-style fyke nets to collect muskie each spring for two purposes – to monitor the relative numbers and sizes of muskie in each population and to collect hatchery broodstock when needed. Comparing the average number of muskie caught per fyke net per day (number per FND) is a good index of population trends from year to year.*

From 1996 through 1999 at Pomme de Terre Lake, the spring fyke net catch rate ranged from two to seven fish per fyke net day (FND) (Table 5). From 2000 through 2003, the catch rate ranged from two to four fish per FND. As the large 2000 year class aged and became more vulnerable to fyke nets, the catch rate increased to 11.0 fish per FND in 2004, 14.9 fish per FND in 2005 (an all-time Missouri high), and 10.6 fish per FND in 2006.

***Terminology tip**: Fisheries management biologists use a parameter called relative stock density (RSD) to describe the percent of fish collected during a population sample that are greater than a fixed minimum stock size and also greater than or equal to any particular size of interest (Anderson and Neumann 1996). In general, fish smaller than the stock size are hard to collect and including them in percentage calculations could add a lot of unpredictable variability to the percentages. For muskie populations, the fixed stock size is 20 inches. In Missouri, a very common size of interest is the statewide minimum length limit of 36 inches. The abbreviation RSD36 refers to the percent of the muskie collected which are at least 20 inches long that are also greater than or equal to 36 inches.*

At Pomme de Terre Lake, the Relative Stock Density (RSD36) was lower than normal in the 2003 through 2005 samples (Table 5). This was related to an increase in 20- to 30-inch muskie in the population rather than a decrease in the density of muskie greater than or equal to 36 inches. In spring 2006, the RSD36 increased to 25% and is expected to increase further as additional muskie from the 2000, 2001, and 2002 year classes reach legal size.

From 1996 to 2002, the fishing effort expended by our Show-Me Muskie Project cooperators to catch a legal muskie ($\geq$ 36 inches) ranged from about 29 to 98 hours (Table 4). In 2003, our cooperators averaged nearly 81 hours for each legal muskie caught; however the high numbers of smaller muskie in the population from the large 2000 year class reduced the average number of hours expended to catch a muskie of any size to 15.8, an all-time low. Both parameters improved in 2004; anglers expended 7.8 hours to catch any size muskie and 23.2 hours to catch a legal muskie. In 2005, both parameters increased somewhat but remained very good; anglers expended 11.6 hours to catch a muskie of any size and 31.5 hours to catch a legal muskie.

In comparison, muskie anglers averaged one muskie per 70 hours in Chautauqua Lake, New York (Mooradian and Shepherd 1973), one muskie per 48 to 58 hours in Cave Run Lake, Kentucky (Axon 1981), one muskie per 71 hours in eight northern Wisconsin lakes (Hanson 1986), and one muskie per 91 hours in Minnesota waters (Younk and Cook 1992).

The positive impact of the large 2000 year class highlights an unanticipated benefit of stocking rates at Pomme de Terre which have varied considerably around the annual target of 4,000 muskie. Stocking low numbers of muskie over several successive years certainly results in a noticeable decrease in the muskie population, in angler catch rates, and even in angler interest. On the other hand, an occasional "pulse" stocking which is 1.5 to 2.0 times (or more) above the target typically has had a positive impact on the muskie population and on angler success and interest. While opportunistic pulse stockings occurred in 1999 (5,419) and 2002 (6,075), the stocking of 10,611 in 2000 was the largest annual stocking in the history of the lake. In the future we will attempt to have a planned pulse stocking at least one out of every six years at Pomme de Terre. We believe this will better mimic trends in natural muskie populations and will help maintain a higher level of "muskie fever" among Missouri's muskie anglers.

Another strength of the muskie program at Pomme de Terre has been the increase of voluntary catch-and-release of legal-sized muskie since stocking started. From 1977 to 1979, anglers released 34% of the legal muskie they caught. This increased to 78% from 1980 to 1983 after catch-and-release promotions by fisheries management biologists and the local chapter of Muskies, Inc. MDC creel surveys indicated that the release rate for muskie was 80 to 96% in 1991 and 1992, and 90 to 100% in 2004 and 2005. Most recently, Show-Me Muskie Project cooperators reported keeping only four muskie from 1996 to 2006.

While MDC fisheries management biologists have been pleased with the success of the muskie program at Pomme de Terre, and at other lakes currently in the program, they continue to strive to produce muskie which would attain lengths greater than 50 inches for anglers to catch. The current Missouri state record of 49.5 inches and 41 pounds, two ounces came from a small number of muskie released into Lake of the Ozarks in the late 1960s. The largest verified angler-caught muskie from Pomme de Terre Lake was 48.5 inches and weighed 30 pounds, 11 ounces (1981). In 2005, anglers at Fellows Lake caught muskie of 48 and 49 inches. An evaluation was initiated in 2002 at Pomme de Terre and Fellows lakes to compare the growth and survival of

muskie fingerlings from Missouri and Kentucky in an attempt to improve the quality of muskie fishing in Missouri. Kentucky muskie from the Licking River and Cave Run Lake reach lengths up to 53 inches and weights up to 44 pounds. A fair number of muskie in Kentucky's Cave Run Lake now exceed 50 inches, while Missouri muskie greater than 46 inches have been quite rare. Our objective is to determine if the Kentucky strain of muskie has greater growth potential in Missouri than our current broodstock. If growth potential is higher, and if production success and survival are at least as good as the current MDC broodstock, utilizing the Kentucky strain as broodstock may be advantageous.

In 2002, 3,000 Kentucky strain and 3,075 Missouri muskie were stocked in Pomme de Terre Lake (Table 2). In 2003, 1,175 Kentucky strain and 2,825 Missouri muskie were stocked. Both stockings in 2002 and 2003 were marked with freeze brands before stocking for future identification. Early recaptures in 2004 indicated that the freeze brands might not be visible after two to three years. However, the freeze brands were visible on several of these fish captured in early 2005 and 2006. No Kentucky strain muskie were stocked in Pomme de Terre Lake in either 2004 or 2005. However, 3,000 Kentucky strain muskie were stocked in 2006.

The Pomme de Terre Chapter of Muskies, Inc. has donated time and money to support the muskie program many times since the chapter was formed in 1975. Recent examples include donations in 2004 and 2005 to support the vegetation establishment project at Pomme de Terre Lake. Chapter monetary donations were leveraged with additional funds from Gander Mountain, Muskies, Inc. International, and the Research Committee of Muskies, Inc.

Forty-four fenced exclosures were built and placed in some of the most suitable locations in the Pomme de Terre Arm of the lake according to procedures developed by Smart et al. (2005). These exclosures were planted with species found to be suitable in other Missouri reservoirs, including water smartweed, spatterdock, water lily, and wild celery (Allman 2006). They were intended to protect the plants from herbivores like turtles and muskrats.

Experimental, unprotected plantings of surplus water smartweed and spatterdock were made in three other locations. Water willow "burritos" (water willow plants rolled in hay bale netting) were constructed and placed at four locations. Establishing and maintaining vegetation in flood-control reservoirs, such as Pomme de Terre, will be a challenge because of the fluctuation in lake levels throughout the year (Smart et al. 2005).

Brush pile or "fish attractor" construction has been an annual project on Pomme de Terre since 1992. This has been a joint project of the U.S. Army Corps of Engineers, Muskies, Inc. volunteers, and MDC. The

effectiveness of the effort was greatly enhanced with the advent of an MDC habitat barge in 1999 and further enhanced by a Bass Tracker donation of a larger habitat barge in 2003. This tree-hauling pontoon boat enables much larger trees to be delivered to desirable locations for accurate placement in various water depths.

A total of 41 brush piles are marked with large reflective signs on the shoreline to allow anglers to easily find them; approximately 140 other unsigned brush piles have been constructed in off-shore locations. Information concerning the location of brush piles at Pomme de Terre can be found on the MDC website.

The Pomme de Terre Lake 2004 and 2005 creel surveys documented angling effort for muskie at 0.62 and 1.98 hours/acre respectively. However, obtaining statistically valid muskie angling data from creel survey has proven to be very difficult, primarily due to the low number of muskie angler contacts and times at which muskie anglers concentrate their efforts. This accounts for large variations in angler effort and catch rates seen in the results from the past and most recent creel surveys. Therefore, further discussion and comparisons of muskie creel survey data has minimal use for future planning. The best trend information we have for relative angler effort and catch rates for muskie comes from information submitted by anglers cooperating in the Show-Me Muskie Project. These anglers make up a large portion of the total angler effort for muskie on Pomme de Terre Lake.

Hazel Creek Lake

Muskie were first stocked in Hazel Creek Lake in 1983, then again in 1990, 1992, 1995, and 1996 (Table 3). Stocking in 2000 and 2001 included an evaluation to determine if larger fingerlings stocked in the spring (12 to 14 inches) would have higher survival rates than typical fall stockings (10 to 12 inches) as was found in three Wisconsin lakes by Margenau (1992).

The spring-stocked muskie at Hazel Creek Lake were freeze-branded to enable future identification. There were two size groups; each was branded in a distinct location (Table 3).

None of the muskie captured in spring 2004, 2005, or 2006 with fyke nets had recognizable freeze brands. Consideration of these results, plus results from a similar evaluation at Lake 35, August A. Busch Conservation Area, indicated no apparent benefit of spring stocking as compared to Missouri's standard fall stocking of muskie.

Hazel Creek Lake has consistently supported a quality muskie population, both in terms of numbers and size, since the mid-1980s. Catch rates from recent fyke netting surveys have been some of the highest and muskie up to 47 inches have been captured (Table 5). One in five muskie captured with fyke nets in 2004 was at least 40 inches, including two fish measuring 45.5 and 47.0 inches. The catch rate of muskie has remained consistent for the past two years, averaging 6.6 fish per FND. In 2005, the catch rate was 6.8 fish per FND, probably due to good survival of the fall 2000/spring 2001 stockings. Two large female muskie (46.0 and 47.3 inches)

were captured. In 2006, catch rates were 6.4 per FND. RSD36 has been fairly consistent and high (25 to 64%) indicating a quality fishery. In 2006, RSD36 was 57%, which was the highest it has been since 1998.

Show-Me Muskie Project results indicate a quality muskie fishery in Hazel Creek Lake (Table 4). From 1996 through 2003, angler catch rates for all sizes of muskie and for muskie greater than 36 inches were quite high. Up to 16 anglers have turned in reports from Hazel Creek Lake annually since 1996. From 1998 to 2001, the number of hours required to catch a muskie at least 36 inches long was better than our objective of 20 to 40 hours. In 2002 and 2003, it took anglers 22 hours, on average, to catch a muskie at least 36 inches. In 2004, this increased to an average of 38.3 hours to catch a muskie at least 36 inches. Even though more than half of the muskie caught by fyke netting were longer than 36 inches, none of our cooperators caught a muskie longer than 36 inches in 2006.

Aquatic vegetation growth has been hampered by recent droughts (1999 to 2000 and 2002 to 2003) during which the lake remained five to six feet below normal pool. The 1,355 grass carp that were stocked between 1986 and 1991 also continue to suppress the growth of submerged aquatic vegetation.

Two large exclosures were constructed out of galvanized woven-wire fencing. Approximately 100 large-leaf pondweed plants were planted in each exclosure in 2003. Survival of the large-leaf pondweed was excellent through 2004. During 2005, it was discovered that a majority of large-leaf pondweed had been displaced by American pondweed. No significant beds of aquatic vegetation were observed growing outside the exclosures, although a few American pondweed plants were observed throughout the lake. The exclosures were removed in the spring of 2006 due to deterioration and because no growth had occurred outside of the structures. During the summer of 2006, American pondweed beds were considerably more numerous than in 2005. Possible explanations for this could be due to more stable water levels and the removal of 40 grass carp by bowfishing anglers. Also during the summer of 2006, three locations, totaling 320 linear feet of shoreline, were planted with water willow.

Fellows Lake

Muskie stocking at Fellows Lake was initiated to meet program expansion objectives in the original muskie plan (Neuswanger et al. 1994). The lake was originally stocked with one muskie per acre in October 1996 (Table 6). The stocking rate was changed to three fish per acre in 1999 and 2002. Since 2004, the rate has been one muskie per acre per year. The lake has generated much muskie fishing excitement and it produced at least two muskie 48 inches or larger in 2005; this represents excellent growth for nine year old muskie.

The muskie population is in good condition as indicated by fyke netting results (Table 5). Fyke netting catch rates have ranged from 1.9 to 3.3 fish per FND, with the lone exception of 2005 (1.0 per FND). RSD36 has varied from 31 to 51%. In 2006, the RSD36 was 31%.

Show-Me Muskie Project results indicate that our cooperators began fishing and catching muskie in Fellows Lake in 2001 (Table 4). It took an average of 13.5 hours to catch a muskie of any size in 2001; no muskie were caught that exceeded 36 inches. Since 2002, the hours to catch a muskie at least 36 inches steadily increased from 10.0 hours in 2002 to 33.3 hours in 2005.

Fellows Lake is also involved in the evaluation of stocking Kentucky strain muskie, as described for Pomme de Terre Lake. In 2002, 400 freeze-branded Kentucky strain and 2,990 unmarked Missouri muskie were stocked in Fellows Lake (Table 6). In 2004, 380 wire-tagged Kentucky strain and 350 unmarked Iowa muskie were stocked. Muskie stocking in 2005 included 550 wire-tagged Kentucky strain and 550 wire-tagged Iowa muskie. During 2006, 410 freeze-branded Kentucky strain muskie and 410 freeze-branded muskie from Iowa were stocked.

Numerous brush piles have been constructed by MDC at Fellows Lake. Efforts are currently underway to replenish and expand these structures. Information concerning the location of brush piles at Fellows Lake can be accessed at the MDC website.

Henry Sever Lake

This lake was originally stocked with muskie in 1996, 1999, and 2002 at a rate of three fingerlings per acre (Table 7). In 2005, the rate was changed to one muskie per acre per year.

Fyke netting indicated that a good muskie population was developing until numerous muskie escaped over the spillway during a heavy spring rain in 2001 (Table 5). Catch rates decreased from 1.8 per FND in 2001 to 0.8 per FND in 2002. Catch rates in 2003 and 2004 were even lower. The 2005 and 2006 fyke net results were encouraging because the catch rate increased to 3.5 and 5.7 fish per FND, respectively, with most of the fish apparently from the 2002 year class. RSD36 was zero from 2002 to 2004. It increased in 2005 to 5% and again in 2006 to 24% indicating that the population is recovering.

Very few muskie fishing trips at Henry Sever Lake have been reported to date by Show-Me Project cooperators and no muskie have been caught (Table 4).

Grass carp also left the lake over the spillway during spring 2001; since then water clarity has improved and some aquatic vegetation has begun to grow. A spillway barrier, that will reduce escapement of muskie, has been designed and is expected to be installed in 2007.

Lake 35, August A. Busch Conservation Area

Lake 35 was initially stocked in October 2001 with 93 fingerlings (Table 8). In spring 2002, 112 yearlings were marked with freeze brands and tagged with coded wire tags before stocking. In the 2006 survey, 13 of the 27 muskie captured had coded wire tags. No differences in size or relative weight were observed between tagged and untagged muskie.

In 2005, the stocking rate was changed to one muskie per acre per year, similar to most of the other muskie program lakes. The total number of muskie stocked at Lake 35 from 2001 through 2006 was 333.

Fyke netting was initiated in 2004 (Table 5). In 2006, the RSD36 was 19% indicating good numbers of legal muskie in the population, but the catch rate fell below two muskie per FND.

Few Show-Me Muskie Project cooperators have reported fishing this lake to date (Table 4). The hours to catch a muskie of any size were 81.0 and 21.8 hours in 2004 and 2005, respectively. Anglers do occasionally catch muskie at Lake 35, but these catches are primarily incidental to other fishing activity or made by new muskie anglers who have not yet become participants in the Show-Me Muskie Project.

Escapement of muskie from Lake 35 has also been a concern, especially in 2004. Various spillway fish passage barriers were considered in 2005, but all were found to be cost prohibitive.

Lake 35 has very good habitat. Coontail and American pondweed typically cover 10 to 20% of the lake by mid-summer. Numerous brush pile projects have improved deep water habitat in the lake. Busch CA Lake 35 will continue to be stocked and evaluated because its proximity to St. Louis could provide unique angling and educational opportunities.

Lakes Removed from the Muskie Program

A goal in the original muskie plan was to increase muskie fishing opportunities for muskie in small impoundments and to expand the geographic distribution of muskie fisheries in Missouri. The procedures and criteria listed in the plan were used to select small lakes for stocking (Neuswanger et al. 1994**).**

From 1995 through 2001, six additional lakes were approved and stocked with muskie: Lake Girardeau, Fellows Lake, Henry Sever Lake, Binder Lake, Lower Taum Sauk Lake, and Busch CA Lake 35. Results from spring fyke netting and the Show-Me Muskie Project were used to evaluate the muskie populations in new and existing lakes. Based on these results, one of the older muskie program lakes (Pony Express Lake) and three of the newer lakes (Lake Girardeau, Binder Lake, and Lower Taum Sauk Lake) were dropped from the muskie program.

CULTURE & HATCHERY OPERATIONS

Historically, most of MDC's warmwater fish hatcheries have contributed to the muskie program. In the early years of the program, fry or eggs were obtained from outside of Missouri and reared to stocking size in Missouri hatcheries. Since 1991, muskie broodstock have frequently been collected from Missouri's program lakes for spawning and rearing of fingerlings at Hunnewell, Chesapeake, or Blind Pony hatcheries. While this has greatly increased our independence in muskie fingerling production, we still rely on other states such as Iowa, Indiana, and Kentucky during periods of production shortages or special evaluations.

Lost Valley Hatchery (LVH) has been involved with spawning and raising muskie fingerlings since opening in 2000. In the first year of operation, muskie production greatly exceeded stocking targets; therefore there was a high number of surplus fingerlings. This was the source of the large 2000 year class at Pomme de Terre Lake.

In recent years, Missouri broodstock have been collected during standardized fyke netting surveys in late March or early April from Pomme de Terre and Fellows lakes. Flowing females are used for egg production. Eggs and semen are taken from the broodstock on-site and the broodstock are released. Fish are raised intensively (in tanks or raceways) up to 3.5 to 4.0 inches on dry artificial feed and placed in ponds for further grow-out on fathead minnows. The target stocking density is 4,000 3.5- to 4-inch fish per half-acre rearing pond. For the production of 5,800 12- to 14-inch fingerlings in non-pulse stocking years, three half-acre ponds are needed and the muskie are fed at least 8,500 to 9,000 pounds of live fathead minnows. To raise 9,800 fingerlings during the pulse stocking years, an additional two half-acre ponds will be needed. MDC has no plans to allocate additional hatchery rearing space for muskie production due to cost and space requirements for other species. Therefore, it is unlikely that the muskie program can be expanded to any substantial degree beyond the current total acreage of lakes in the muskie program.

Avian piscivores, primarily great blue herons, can cause problems in hatcheries (Glahn 1999a, Glahn 1999b, Glahn and Dorr 2000). MDC began covering our half-acre rearing ponds dedicated to the muskie program with avian predator netting to increase production. The netting has been successful in reducing bird predation on small muskie and their forage. The initial nets were donated by the Shawnee Muskie Hunters and Pomme de Terre chapters of Muskies, Inc. in 2001.

Two fisheries management challenges have had a direct impact on hatchery operations for muskie. In September 2000, anglers at Pomme de Terre Lake notified MDC of herons feeding on recently stocked 10- to 12-inch muskie fingerlings. Fisheries staff inspected the site and found approximately 50 dead muskie fingerlings, most with obvious injuries caused by herons. As a result, a decision was made to stock larger muskie fingerlings (12 to 14 inches) later in October each year and to stock them later in the day to reduce heron and bass predation. Increasing the size of fingerlings at stocking should decrease vulnerability to predation by largemouth bass and enhance survival of newly stocked fingerlings (Carline et al. 1986; Hanson et al. 1986; McKeown et al. 1999; and Szendrey and Wahl 1996). Raising the average length of stocked muskie by approximately two inches increases production costs because it requires approximately 4,000 additional pounds of minnows each year.

The evaluation of the Kentucky strain of muskie at Pomme de Terre and Fellows lakes added some complexity and expense to muskie production from 2002 to 2006. However, it is hoped that this strategy will enhance the quality of Missouri's muskie fisheries by resulting in an increased maximum size that could be caught by anglers. For the strain evaluation, LVH obtained fertilized eggs from the Kentucky Department of Fish and Wildlife Resources about three weeks after the normal spawning time for Missouri muskie. The different strains were kept separate in the hatchery and had different growth rates and feeding behaviors. Freeze branding or marking of fingerlings was used to provide identification of the strains when recaptured years later. Tables 2 and 6 include the distribution of Kentucky strain muskie. Evaluation of stocking the Kentucky strain will continue throughout the term of this plan, and possibly beyond. Success of these stockings will be judged on the survival, growth, and maximum size of the Kentucky strain as compared with fingerlings produced from other broodstock sources, such as Missouri, Iowa, and Indiana.

There are two other possible options for increasing the growth potential and average size of muskie in Missouri. One would involve increasing the ratio of females to males produced and stocked. It has been shown that the sex ratios of some species, such as trout, can be altered by subjecting the fertilized eggs to short-term temperature shock (Galbreath and Samples 2000; Thorgaard and Jazwin 1981). Females grow faster and larger than males. Therefore, the average size and ultimate size of caught fish could be increased by having a higher percentage of females in Missouri lakes. Heidinger et al. (2002) attempted unsuccessfully to produce all-female muskie progeny. Another option may be the production of genetically altered "triploid" muskie fingerlings. These muskie would be mostly sterile and would therefore direct energy normally consumed by reproduction into growth instead.

Both of these options would have an effect on our broodstock source lakes if successful. Thus, provisions for maintaining broodstock quality and availability would have to be developed if either of these options were pursued.

An additional method of marking muskie has been investigated and will be used in conjunction with physical marks and tags. From 2001 to present, a small sample of fin tissue has been removed from stocked fish that represent several stocking sources (states) and year classes. The intention is to document any easily identifiable DNA genetic differences among stockings in the event that physical markers or tags are not identifiable on muskie when they are captured as large, old fish. For year classes and sources that have distinguishing DNA markers, a fin or tissue sample could be removed without injuring the muskie, and be used to identify its stocking

origin. These natural genetic markers vary by hatchery stock depending on broodstock selection and representation of offspring in fish received by Missouri. Distinct genetic markers have been found for identifying the 2001 Kentucky strain versus Missouri sources (Fellows Lake, representing Hazel Creek Lake fish from the Linesville, Pennsylvania hatchery strain, and Pomme de Terre Lake); and in 2002 for Pomme de Terre Lake versus Kentucky strain and Fellows Lake (*i.e.* the latter two sources were the same). Iowa and Kentucky offspring from 2005 and 2006 will also be analyzed.

LOOKING TO THE FUTURE

The success of Missouri's muskie program to date can largely be attributed to the interest of Missouri's muskie anglers and their support of the cooperative efforts of hatchery and fisheries management personnel of the Missouri Department of Conservation. It is essential to maintain and enhance this support, cooperative spirit, and communication.

The following objectives and strategies will guide Missouri's muskie management and culture efforts. This plan will also serve as a tool to help communicate program direction to anglers.

MISSION, GOAL, OBJECTIVES, & STRATEGIES

The mission of the muskie program is to provide special, high-quality angling opportunities in suitable, well-distributed impoundments where more traditional Missouri fisheries will not be adversely affected and may be enhanced.

The goal of this plan is to provide a framework for developing and maintaining high-quality muskellunge (muskie) fisheries for anglers in Missouri.

Objective I: Stock 12- to 14-inch muskie fingerlings each fall in all muskie program lakes under 1,000 acres (Hazel Creek Lake, Fellows Lake, Henry Sever Lake, and Lake 35, August A. Busch Conservation Area) and assess/adjust stocking based on available data.

Strategies:

- Stock one muskie fingerling per acre.
- Population size structure, growth, relative weight, and angler success will be monitored as per Objectives IV, V, and VI; stocking rates will be adjusted if necessary.
- The muskie work group will set criteria, based on fyke net and Show-Me Muskie Project data, plus lake-specific information, to either adjust stocking rates or to determine if any lake(s) should be removed from the muskie program. Fisheries management biologists will use these criteria to evaluate their muskie populations and make recommendations to the muskie work group at their annual meetings. The muskie work group will discuss regional staff proposals and make recommendations to Fisheries Administration for implementation.

Objective II: Stock 12- to 14-inch muskie fingerlings each fall at Pomme de Terre Lake under a "pulse" stocking regime and assess/adjust stocking based on available data.

Strategies:

- Stock 4,000 fingerlings per year in five out of every six years.
- Stock 6,000 to 8,000 fingerlings in one out every six years.
- The first six-year period will be from 2008 through 2013.
- The six-year maximum stocking will be 28,000 muskie. If the pulse stocking cannot be achieved in any six-year period, no attempt will be made to change the numbers stocked or the maximum stocking during the next six year period.

- Population size structure, growth, relative weight, and angler success will be monitored as per Objectives IV, V, and VI; stocking rates will be adjusted if necessary.
- The muskie work group will set criteria, based on fyke net and Show-Me Muskie Project data, plus lake-specific information, to adjust stocking rates as needed. Fisheries management biologists will use these criteria to evaluate their muskie populations and make recommendations to the muskie work group at their annual meetings. The muskie work group will discuss regional staff proposals and make recommendations to Fisheries Administration for implementation.

Objective III: Produce or acquire 12- to 14-inch muskie fingerlings to meet stocking objectives.

Strategies:

- Use Pomme de Terre and Fellows lakes as sources of Missouri broodstock for hatchery production in years when eggs or fingerlings are not supplied by other states.
- Collect Missouri broodstock and fertilize eggs on-site; release broodstock at the collection site.
- Hatch eggs at a MDC hatchery and rear muskie on dry artificial feed to four inches prior to moving them to ponds to be fed on fathead minnows until they reach 12 to 14 inches for fall stocking.
- Evaluate stocking densities in hatchery ponds to increase the number of muskie raised per acre while maintaining average stocking size.
- Continue efforts to characterize the genotype of our broodstock; and ensure that genetic diversity is maintained among gametes used in fingerling production by soliciting input from our Fisheries Geneticist prior to broodstock collection.
- Investigate the feasibility of producing triploid and/or predominately female muskie for stocking in selected lakes and, as feasible and appropriate, implement and evaluate this technique for enhancing the growth rates and size structure of muskie in Missouri.

Objective IV: Maintain density and size structure of muskie populations that result in average annual angler catch rates of one muskie at least 36 inches long per 20 to 40 hours of muskie fishing effort (as reported by Show-Me Muskie Project cooperators).

Strategies (stocking and regulations):

- Stock muskie fingerlings annually as per Objectives I and II.
- Maintain the statewide minimum length limit of 36 inches (including Hazel Creek Lake as of March 1, 2008).
- Maintain the statewide daily limit of one muskie.

Strategies (assessment):

- Continue to use Show-Me Muskie Project results to assess angler catch rates.
  - ✓ Encourage current cooperators to remain active.
  - ✓ Recruit additional cooperators at all program lakes.
  - ✓ Share annual summary of Show-Me Muskie Project results with all cooperators.

Objective V: Evaluate muskie populations at each program lake through fyke net surveys with Wisconsin-style nets.

Strategies:

- Each lake will be surveyed at least every other year.
- Assessments will be conducted annually during periods of special management or regulation evaluations.
- Parameters to be monitored will include: average number of muskie caught per fyke net per day (number per FND); RSD36; and in many cases, relative weight (Wr).
- The target numbers of muskie to be sampled for determining RSD36 (both sexes) or Wr (males only) are: 90 for Pomme de Terre, Hazel Creek, and Fellows lakes; 75 for Henry Sever Lake; and 55 for Lake 35 (Steve Sheriff, MDC, personal communication).
- Sampling will be limited to a maximum of five days to minimize potential handling stress on muskie.
- If new muskie lakes are added to the program they will be sampled beginning in the fourth year after the initial stocking.
- Regional Fisheries staff will work with the Muskie Program Coordinator and Resource Science staff to evaluate existing data, segregated by sex and strain as appropriate, to determine what relationships exist between muskie stocking rates vs. fyke net catch rates, growth, Wr, and angler catch rates (Show-Me Muskie Project data). Results of this evaluation will be used to establish an objective for fyke net catch rate.

***Terminology tip**: Many fisheries management biologists use a parameter called relative weight to describe the "well-being" or body condition of fish collected during population sampling. Measures of body condition are typically based on a comparison of each individual fish to the "standard weight" of a fish of the same species and length as described by Anderson and Neumann (1996). In theory, relative weights equal or slightly greater than 100 are optimal.*

Objective VI: Continue the muskie strain evaluation at Pomme de Terre and Fellows lakes throughout the term of this plan.

Strategies:

- Statistically evaluate growth, relative weight, survival, maximum size, and other performance characteristics of the Kentucky strain compared with muskie fingerlings produced from northern strain broodstock.
- Use the Kentucky versus northern strain evaluation data to establish an age/growth relationship.
- Determine the desired strain and sources for future stocking in all Missouri muskie lakes and adjust broodstock collections and hatchery operations accordingly.

Objective VII: Evaluate opportunities to establish additional muskie fishing opportunities if any of the current muskie program lakes are dropped from the program.

Strategies:

- Periodically solicit input from Fisheries regional staff regarding potential additions to the program.
- Proposed lakes must meet most of these criteria:
    - ✓ Appropriate geographic distance and position relative to other Missouri muskie lakes.
    - ✓ Low likelihood of dissolved oxygen or water temperature regimes that might threaten muskie survival or hinder their growth for prolonged periods of time (mid-summer dissolved oxygen concentration must exceed 5 mg per liter at water temperatures less than 90 degrees F in order for muskie to survive and less than 85 degrees F for them to grow at adequate rates.)
    - ✓ Water transparency (Secchi disk) almost always 24 inches or greater. This will facilitate muskie growth and maximize angler enjoyment of muskie encounters.
    - ✓ Gizzard shad present (primary prey for age-1 and older muskie).
    - ✓ Availability of other preferred prey, such as brook silversides, golden shiner, common carp, or redhorse suckers.
    - ✓ Substantial areas of submerged and emergent aquatic plants, flooded timber, and brush piles.
    - ✓ A barrier to emigration via the outlet structure or emergency spillway; or watershed characteristics such that the frequency and magnitude of flushing flows are very low (suggested ratio 15 to1 or less, preferably with a tower outlet, but no greater than 20 to1 without a barrier which will retain age-3-and-older fish)
    - ✓ Not subject to inundation by a nearby stream.
    - ✓ Provide unique angling and educational opportunities.

Objective VIII: Improve aquatic habitat to benefit muskie and other species.

Strategies:

- Pomme de Terre:
    - ✓ Continue to evaluate the ongoing vegetation establishment project to establish lake specific methodology, species, resource value, success, and feasibility of expanding the project to other Pomme de Terre Lake locations beginning in 2008.
    - ✓ Continue to construct brush piles and hinge-cut shoreline trees to improve fish habitat utilizing MDC resources, U.S. Army Corps of Engineers contributions, outside grant funding, and Muskies, Inc. volunteers.
    - ✓ Continue to work with the U.S. Army Corps of Engineers to refine water level management recommendations to promote aquatic vegetation growth and increased fish productivity.
- Fellows Lake:
    - ✓ Replenish existing brush piles on an 8- to 10-year cycle.
    - ✓ Hinge cut trees in selected locations in cooperation with City Utilities of Springfield.
    - ✓ Monitor coontail population
- Hazel Creek Lake:
    - ✓ Monitor the natural expansion of American pondweed.
    - ✓ Continue to evaluate the 2006 water willow plantings.

- ✓ Promote bow fishing for grass carp.
- ✓ Attempt to remove 25-50 grass carp annually during normal management activities and by cool-water electrofishing.
- ✓ Once grass carp numbers have decreased, restoring aquatic vegetation will be considered if natural populations do not proliferate.

- Henry Sever Lake
  - ✓ Monitor aquatic vegetation annually.
  - ✓ Replenish existing brush piles as needed
- Lake 35
  - ✓ Monitor aquatic vegetation annually.
  - ✓ Replenish existing brush piles as needed

Objective IX: Ensure that anglers know about opportunities for muskie fishing in Missouri.

Strategies:

- Inform the public of Missouri muskie fishing opportunities through periodic news releases, television and radio interviews, and magazine articles (including the *Missouri Conservationist*).
- Managers of muskie lakes and hatcheries should capitalize on opportunities to invite reporters to do stories on muskie management and culture operations.
- Periodically update MDC's muskie brochure in order to reflect the current status of Missouri muskie fisheries.
- Encourage Muskies, Inc. and similar angler groups to assist MDC in educating anglers about muskie fishing statewide.
- Post the muskie release poster at lakes managed for muskie and distribute the poster to local bait shops and marinas.
- Fisheries management biologists will provide an annual update to the Muskie Program Coordinator which will include spring fyke-netting results and other information which will be posted MDC's muskie web page.

Objective X: Maintain partnerships with other agencies, Muskies, Inc., and other muskie anglers.

Strategies:

- The Muskie Program Coordinator will be MDC's liaison with Muskies, Inc., Show-Me Project cooperators, and other muskie anglers. Local fisheries management biologists will be the primary contacts for local anglers, affiliated angler groups, local government partners, and the media regarding muskie management on their respective lakes.
- The coordinator will promote the Show-Me Muskie Project, summarize the results, and distribute information to the Muskie Work Group and cooperators.
- The coordinator will serve as the MDC representative at meetings of the Esocid Technical Committee of the North Central Division of the American Fisheries Society.

Objective XI: Continue efficient implementation of this plan.

Strategies:

- The Muskie Program Coordinator will lead a muskie work group comprised of hatchery staff, fisheries management biologists, and fisheries administrators involved in muskie management.
- The muskie work group will have at least one muskie coordination meeting each year to discuss management, stocking, culture, and other activities and opportunities.

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Table 1. General information for current Missouri muskie lakes.

Lake	Surface Acres	Minimum Length Limit (in)	County Location	Year Initially Stocked	Boat/Outboard Motor Restrictions
Pomme de Terre	7820	36	Hickory and Polk	1966	None
Hazel Creek	530	42	Adair	1983	Trolling motor only
Fellows	820	36	Green	1996	40 HP maximum
Henry Sever	158	36	Knox	1996	Trolling motor only
Lake 35, Busch CA	62	36	St. Charles	2001	Rental boats only

Table 2. Muskie stocking history for Pomme de Terre Lake.

Year Stocked	Month	Number	No./Acre	Size (in)	Strain/Origin	Freeze Brand Location
2006	October	2,490	0.3	10-12	Wisconsin strain from Iowa	L/PEL
2006	October	3,000	0.4	10-12	Kentucky	R/PEL
2006*	February	2,034	0.3	11-12	Indiana	
2005	November	2,760	0.4	10	Indiana	
2005	October	2,682	0.3	10-12	Iowa	
2004	October	2,040	0.3	10-12	Iowa	
2003	October	2,825	0.4	12-14	Missouri--Fellows Lake	L/DOR
2003	October	1,175	0.2	12-14	Kentucky	R/DOR
2002	October	3,075	0.4	10-12	Missouri--Pomme de Terre	L/PEC
2002	October	3,000	0.4	10-12	Kentucky	R/PEC
2001	October	2,428	0.3	12-14	MO-Fellows/Pomme de Terre	
2000	October	10,611	1.4	10-12	Missouri--Pomme de Terre	
1999	October	5,253	0.7	10-12	Missouri--Hazel Creek Lake	
1999	March	166	0.02	12-14	Missouri--Hazel Creek Lake	
1998	October	853	0.1	2-4	Missouri--Pomme de Terre	
1998	October	2,210	0.3	10-12	Missouri--Pomme de Terre	
1997	November	3,205	0.4	8-10	Missouri--Hazel Creek Lake	
1997	October	2,585	0.4	10-12	Missouri--Hazel Creek Lake	
1996	October	7,000	0.9	10-12	Iowa--Spirit Lake	
1995	October	2,813	0.4	12-14	Missouri--Pomme de Terre	
1994	October	604	0.1	6-8	Iowa	
1994	October	4,247	0.5	8-11	Missouri	
1994	October	1,209	0.2	10-12	Missouri	
1993	October	212	0.03	10-12	Minnesota--Leech Lake strain	
1993	October	1,764	0.2	12-14	MO--Hazel Creek and Pomme	
1992	November	1,413	0.2	12-14	Missouri--Hazel Creek Lake	
1992	October	441	0.1	10-12	Missouri--Hazel Creek Lake	
1992	October	3,029	0.4	12-14	Missouri--Hazel Creek Lake	
1992	September	1,676	0.2	12-14	Missouri--Hazel Creek Lake	
1992	September	56	0.01	10-12	Missouri--Hazel Creek Lake	
1992**	Spring	969	0.1	10-12	Minnesota--Forest Lake	
1991	October	1,120	0.1	10-12	MO--Hazel Creek and Pomme	
1991	October	1,440	0.2	12-14	MO--Hazel Creek and Pomme	
1990	October	2,788	0.4	10-12	Wisconsin	
1990	October	1,212	0.2	10-12	Minnesota--Leech Lake strain	
1989	October	1,143	0.1	12-14	Minnesota--Leech Lake strain	
1989	October	4,879	0.6	12-14	Wisconsin/Kentucky	
1988	October	646	0.1	10-12	Pennsylvania/North Dakota	
1987	N/A	0				
1986	October	3,817	0.49	8-14	Unknown	
1985	October	961	0.1	10-12	Unknown	
1984	October	3,627	0.5	10-12	Unknown	
1983	October	2,575	0.3	10-12	Unknown	
1982	October	1,676	0.2	10-12	Unknown	
1981	October	835	0.1	12-14	Unknown	
1980	October	150	0.02	12-14	Unknown	
1979	September	1,186	0.2	11-13	Unknown	

Table 2. continued

Year Stocked	Month	Number	No./Acre	Size (in)	Strain/Origin	Freeze Brand Location
1978	October	3,365	0.4	12-15	Unknown	
1977	October	2,393	0.3	10-12	Unknown	
1976	September	500	0.1	12-14	Bear Lake Fish Hatchery	
1976	September	750	0.1	6-12	Valley City National Hatchery	
1975	Unknown	298	0.04	9-11	Unknown	
1974	Unknown	223	0.03	9-11	Unknown	
1973	N/A	0				
1972	September	420	0.1	8-10	Unknown	
1971	N/A	0				
1970	Unknown	298	0.04	9-11	Unknown	
1969	Unknown	11,200	1.4	Fry	Unknown	
1969	September	370	0.05	9-11	Unknown	
1968	June	7,711	1.0	Fry	Unknown	
1968	March	798	0.1	9-11	Unknown	
1967	Unknown	12,850	1.6	Fry	Unknown	
1967	Unknown	835	0.1	7-15	Unknown	
1966	Unknown	51,000	6.5	Fry	Unknown	
1966	Unknown	1,507	0.2	7-15	Unknown	

L/PEL - left side, above pelvic fin
R/PEL - right side, above pelvic fin
L/DOR - left side, between dorsal fin and tail
R/DOR - right side, between dorsal fin and tail
L/PEC - left side, near tip of pectoral fin, behind gill cover
R/PEC - right side, near tip of pectoral fin, behind gill cover

* Held over from 2005 at Chesapeake Hatchery and stocked in 2006
** Held over from 1991 at Blind Pony Hatchery and stocked in 1992

Table 3. Muskie stocking history for Hazel Creek Lake.

Date	Number	No./Acre	Size (in)	Strain/Origin	Freeze Brand Location
Oct. 2006	530	1.0	10-12	Wisconsin strain from Iowa	
Oct. 2005	530	1.0	10-12	Iowa	
Mar. 2001	207	0.4	11.9	Missouri-Fellows Lake	L/Anal fin
Mar. 2001	169	0.3	13.3	Missouri-Fellows Lake	R/PEC
Oct. 2000	684	1.3	10-12	Missouri-Pomme de Terre Lake	
Oct. 1996	530	1.0	10-12	Missouri-Hazel Creek Lake	
Oct. 1995	530	1.0	12-14	Missouri-Hazel Creek Lake	
Apr. 1992	530	1.0	10-12	Minnesota-Leech Lake strain	
Oct. 1990	200	0.4	10-12	ennsylvania-Linesville Fish Culture Station	
Oct. 1990	330	0.6	12-14	Minnesota-Leech Lake strain	
Oct. 1983	1,500	2.8	10-12	ennsylvania-Linesville Fish Culture Station	

L - Left side
R/PEC - right side, near tip of pectoral fin, behind gill cover

Table 4. Show-Me Muskie Project Results.

Lake	No. of Trips	No. of Anglers	Total Hours	No. of Encounter	Hrs. per Encounter	No. Caught	Hrs. per Catch	No. Caught	Hrs. per Catch >36"
Pomme de Terre									
1996	162	?	1035	97	10.7	33	31.4	20	51.8
1997	113	12	719	115	6.3	43	16.7	25	28.8
1998	50	7	294	17	17.3	5	58.8	3	98.0
1999	53	13	368	32	11.5	15	24.5	7	52.6
2000	205	39	1201	67	17.9	43	27.9	24	50.0
2001	138	25	812	83	9.8	33	24.6	17	47.8
2002	221	27	1418.5	199	7.1	72	19.7	18	78.8
2003	294	50	1616	364	4.4	102	15.8	20	80.8
2004	407	54	2181	622	3.5	278	7.8	94	23.2
2005	348	38	2048	414	4.9	177	11.6	65	31.5
Hazel Creek									
1996	99	?	768	219	3.5	94	8.2	55	14.0
1997	130	16	941	174	5.4	55	17.1	39	24.1
1998	58	7	485	64	7.6	34	14.3	27	18.0
1999	72	9	562	50	11.2	46	12.2	35	16.1
2000	107	13	810	109	7.4	57	14.2	50	16.2
2001	26	7	220	36	6.1	27	8.1	27	8.1
2002	23	7	151	15	10.1	8	18.9	7	21.6
2003	17	7	87	6	14.5	5	17.4	4	21.8
2004	31	5	153	30	5.1	11	13.9	4	38.3
2005	17	5	102	12	8.5	1	102.0	0	N/A

Lake	No. of Trips	No. of Anglers	Total Hours	No. of Encounter	Hrs. per Encounter	No. Caught	Hrs. per Catch	No. Caught	Hrs. per Catch >36"
Fellows									
2000	0	0	0	0	N/A	0	N/A	0	N/A
2001	6	5	27	3	9.0	4	13.5	0	N/A
2002	18	6	110	25	4.4	14	7.9	11	10.0
2003	47	12	259	41	6.3	22	11.8	15	17.3
2004	45	9	284	39	7.3	27	10.5	11	25.8
2005	85	9	366	52	7.0	22	16.6	11	33.3
Henry Sever									
2000	3	2	15	0	N/A	0	N/A	0	N/A
2001	5	4	33	0	N/A	1	33.0	0	N/A
2002	0	0	0	0	N/A	0	N/A	0	N/A
2003	6	4	31.5	1	31.5	0	N/A	0	N/A
2004	2	1	9	1	9.0	0	N/A	0	N/A
2005	0	0	0	0	N/A	0	N/A	0	N/A
Lake 35, Busch C.A.									
2002	0	0	0	0	N/A	0	N/A	0	N/A
2003	1	1	4	0	N/A	0	N/A	0	N/A
2004	20	3	81	4	20.3	1	81.0	0	N/A
2005	8	3	44	2	21.8	2	21.8	0	N/A

Table 4. continued

Lake	No. of Trips	No. of Anglers	Total Hours	No. of Encounter	Hrs. per Encounter	No. Caught	Hrs. per Catch	No. Caught	Hrs. per Catch >36"
Pony Express									
1996	13	?	65	1	65.0	0	N/A	0	N/A
1997	10	6	61	2	30.5	0	N/A	0	N/A
1998	3	3	19	0	N/A	0	N/A	0	N/A
1999	24	8	147	4	36.8	4	36.8	1	147.0
2000	32	5	167	5	33.4	2	83.5	0	N/A
2001	5	1	27	1	27.0	1	27.0	0	N/A
2002	6	2	29.5	1	29.5	0	N/A	0	N/A
2003	5	2	28	0	N/A	0	N/A	0	N/A
2004	0	0	0	0	N/A	0	N/A	0	N/A
Girardeau									
1999	2	2	14	0	N/A	0	N/A	0	N/A
2000	4	4	27	0	N/A	0	N/A	0	N/A
2001	1	1	5	0	N/A	0	N/A	0	N/A
2002	2	2	6+	0	N/A	0	N/A	0	N/A
2003	1	1	6.5	0	N/A	0	N/A	0	N/A
2004	0	0	0	0	N/A	0	N/A	0	N/A

Lake	No. of Trips	No. of Anglers	Total Hours	No. of Encounter	Hrs. per Encounter	No. Caught	Hrs. per Catch	No. Caught	Hrs. per Catch >36"
Binder									
2000	4	3	24	0	N/A	0	N/A	0	N/A
2001	1	1	5	0	N/A	0	N/A	0	N/A
2002	0	0	0	0	N/A	0	N/A	0	N/A
2003	4	2	10.5	1	10.5	0	N/A	0	N/A
2004	0	0	0	0	N/A	0	N/A	0	N/A
Lower Taum Sauk									
2001	0	0	0	0	N/A	0	N/A	0	N/A
2002	0	0	0	0	N/A	0	N/A	0	N/A
2003	0	0	0	0	N/A	0	N/A	0	N/A
2004	0	0	0	0	N/A	0	N/A	0	N/A

Table 5. Muskie Sampling (Fyke Nets) Results.

Lake	Effort No. FND	Total Caught	Catch Rate (No./FND)	PSD	RSD36
Pomme de Terre					
1996	89	212	2.4	98	37
1997	62	276	4.5	91	41
1998	9	59	6.6	90	42
1999	29	77	2.7	91	39
2000	67	132	2.0	94	39
2001	73	198	2.7	94	49
2002	61	150	2.5	67	34
2003	73	292	4.0	49	12
2004	20	219	11.0	85	10
2005	8	138	14.9	94	15
2006	14	148	10.6	97	25
Hazel Creek					
1996	12	63	5.2	98	33
1997	4	27	6.8	100	56
1998	6	67	11.2	100	64
1999	4	38	9.5	100	55
2000	NS	NS	NS	NS	NS
2001	8	22	2.8	100	36
2002	8	34	4.3	94	47
2003	4	15	3.7	60	40
2004	8	32	4.0	63	25
2005	4	27	6.8	100	48
2006	8	51	6.4	100	57
Fellows					
2000	24	82	3.4	100	36
2001	48	90	1.9	94	51
2002	42	137	3.3	72	36
2003	45	93	2.1	96	27
2004	24	52	2.2	96	44
2005	20	19	1.0	63	21
2006	28	84	3.0	100	31

Table 5. continued

Lake	Effort No. FND	Total Caught	Catch Rate (No./FND)	PSD	RSD36
Lake 35, Busch C.A.					
2004	12	24	2.0	17	0
2005	13	27	2.1	100	7
2006	16	27	1.7	96	19
Henry Sever					
2000	28	15	0.5	100	0
2001	12	21	1.8	90	0
2002	12	10	0.8	90	0
2003	8	5	0.6	100	0
2004	7	2	0.3	100	0
2005	9	22	2.4	41	5
2006	14	80	5.7	98	24
Pony Express					
2000	20	47	2.4	40	0
2001	20	57	2.9		30
2002	NS	NS	NS	NS	NS
2003	15	60	4.0	100	2
Girardeau					
2000	28	3	0.1	100	0
2001	47	11	0.2	73	27
2002	18	4	0.2	100	25
2003	23	5	0.2	100	60
2004	NS	NS	NS	NS	NS
2005	18	2	0.1	100	0
Binder					
2000	32	14	0.4	100	15
2001	18	5	0.3	100	40
2002	NS	NS	NS	NS	NS
2003	20	16	0.8	93	7

Table 5. continued

Lake	Effort No. FND	Total Caught	Catch Rate (No./FND)	PSD	RSD36
Lower Taum Sauk					
2002	16	4	0.3	100	0

NS=No sample

No./FND refers to the average number of muskies caught per fyke net per day.

PSD refers to the percent of the muskies collected which are at least 20 inches long that are also greater than or equal to 30 inches.

RSD36 refers to the percent of the muskies collected which are at least 20 inches long that are also greater than or equal to 36 inches.

Table 6. Muskie stocking history for Fellows Lake.

Date	Number	No./Acre	Size (in)	Strain/Origin	Type of Mark/Tag	Mark/Tag Location
Oct. 2006	410	0.5	10-12	Wisconsin strain from Iowa	FB	L/PEL
Oct. 2006	410	0.5	10-12	Kentucky	FB	R/PEL
Oct. 2005	550	0.7	10-12	Kentucky	WC	L/Cheek
Oct. 2005	550	0.7	10-12	Iowa	WC	Anal fin
Oct. 2004	350	0.4	10-12	Iowa		
Nov. 2004	380	0.5	11.7-13.5	Kentucky	WC	R/Cheek
Oct. 2002	2,590	3.2	10-12	Missouri-Fellows Lake		
Oct. 2002	400	0.5	10-12	Kentucky	FB	R/PEC
Oct. 1999	2,460	3.0	10-12	Missouri-Hazel Creek Lake		
Oct. 1996	820	1.0	11-14	Missouri-Hazel Creek Lake		

FB-Freeze Brand
WC-Wire Coded Tag
L/PEL - left side, above pelvic fin
R/PEL - right side, above pelvic fin
R/PEC - right side, near tip of pectoral fin, behind gill cover

Table 7. Muskie stocking history for Henry Sever Lake.

Date	Number	No./Acre	Size (in)	Strain/Origin
Oct. 2006	38	0.2	10-12	Wisconsin strain from Iowa
May 2006	127	0.8	11-12	Indiana
Oct. 2005	158	1.0	10-12	Iowa
Oct. 2002	474	3.0	10-12	Missouri-Fellows Lake
Oct. 1999	474	3.0	10-12	Missouri-Hazel Creek Lake
Oct. 1996	474	3.0	10-12	Missouri-Hazel Creek Lake

Table 8. Muskie stocking history for Lake 35 (Busch Conservation Area).

Date	Number	No./Acre	Size (in)	Strain/Origin	Type of Mark/Tag	Mark/Tag Location
May 2006	64	1.0	12-14	Indiana		
Oct. 2005	64	1.0	10-12	Iowa		
Mar. 2002	112	1.8	12-14	Missouri-Fellows Lake	FB & WC	R/Vent
Oct. 2001	93	1.5	12-14	Missouri-Fellows Lake		

FB-Freeze Brand
WC-Wire Coded Tag
R-Right side

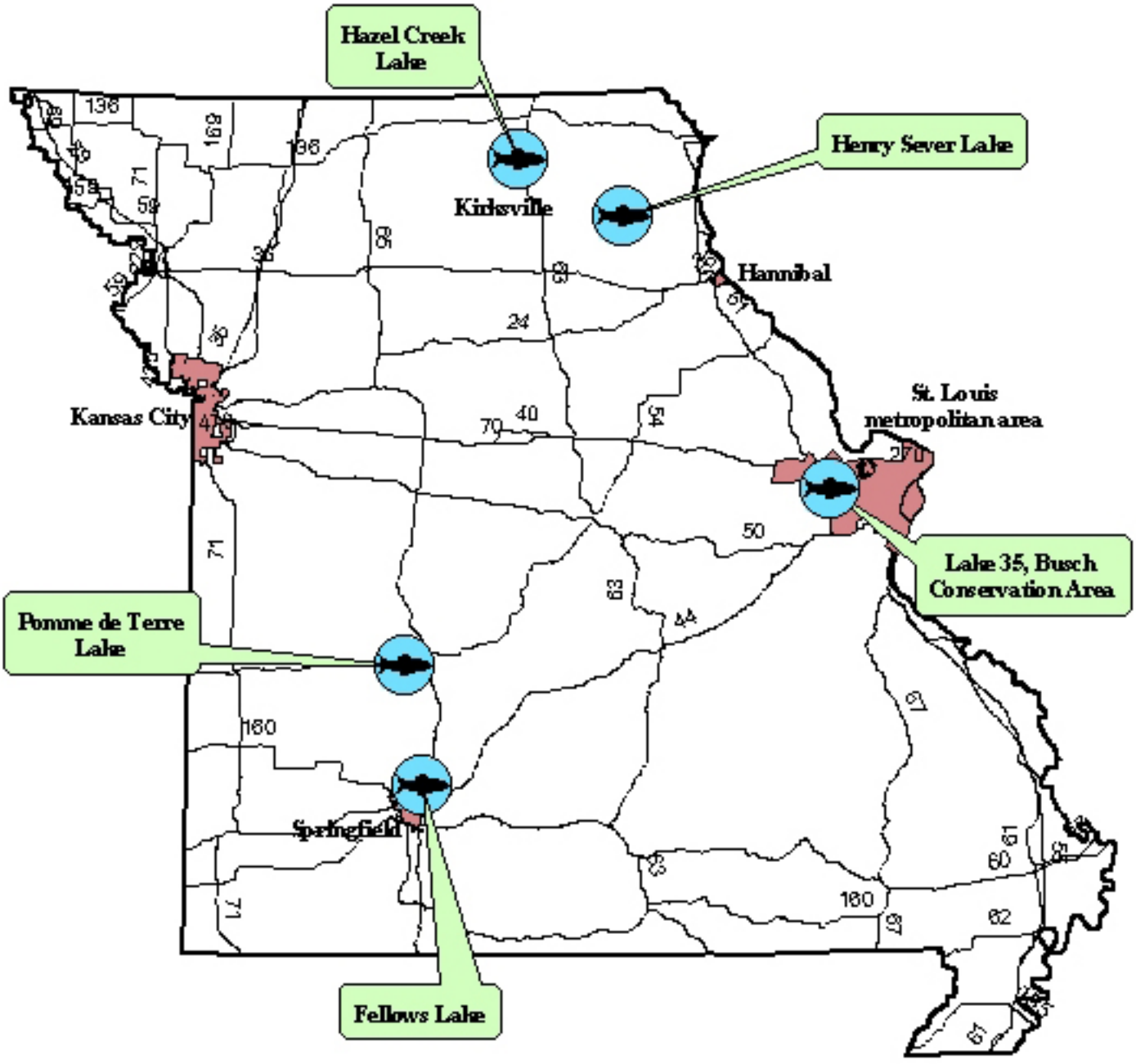

Figure 1, Map of Missouri muskie lakes.

APPENDIX

(Excerpts from the 1994 Muskie Plan; Neuswanger et al. 1994)

Historical Characteristics and Interests of Missouri's Muskie Anglers

In preparing the first muskie plan we learned a number of important things from two public workshops which were held in Kansas City and St. Louis. Eighty-five percent of muskie anglers belonged to a muskie club. Over two-thirds favored introducing muskie into several small public lakes if muskie fishing opportunities could become better distributed. Muskie anglers strongly supported current lake-specific harvest regulations; but when asked at what minimum length a Missouri muskie should be legally harvestable, the average response was 36 inches. Finally, workshop participants strongly encouraged us to designate a liaison to the muskie angling community who could regularly inform them of muskie program progress on a statewide level.

The Pomme de Terre Chapter of Muskies, Inc. was formed in 1975. They typically operate a booth at major sports shows in Kansas City, St. Louis, and other locations to promote Missouri's muskie fisheries and sign-up new members. They also maintain a web page that promotes muskie fishing while informing viewers of club activities. Their substantial donations to the Department of Conservation ($14,950 from 1976 to 1993) encouraged program development. Since then, Muskies, Inc. provided $3,000 to help fund an aquatic vegetation establishment program in Pomme de Terre, purchased several fyke nets, and donated several nets to cover hatchery rearing ponds to prevent avian predation on young muskie. Muskies, Inc. members have also donated many hours to help install large brush piles and plant vegetation in Pomme de Terre Lake.

Statewide angler surveys showed there were 1,000 to 2,000 anglers who fished for muskie from 1983 through 1988. Of the 5,348 days fished per year, 88% occurred at Pomme de Terre Lake, 9% at Hazel Creek Lake, and 3% at Pony Express Lake (S. Weithman, MDC, unpublished data).

Economic Value of Missouri's Muskie Fisheries

Our best historic estimate of the economic value of Missouri's muskie fishery was based upon estimates of effort and contingent dollar value per day of fishing at reservoirs. Annual value from 1983 through 1988 was estimated to be $256,700. Applying the annual consumer price index (CPI-U) to this figure would place the 2006 value of Missouri's muskie program at approximately $424,000.

Belusz and Witter (1986) conducted a survey of entrants at the annual muskie tournament at Pomme de Terre Lake in 1981. Total tournament expenditures averaged $193.54 per respondent for the 2.5-day tournament. When extrapolated to include all entrants (N = 269), total expenditures were $18,455. By using appropriate income multipliers, the total benefit of this tournament to the local economy was estimated to be $35,233.

Muskie Stock Origin and Identification

The Linesville Fish Culture Station located at Lake Pymatuning in Linesville, Pennsylvania has provided many of the young muskie stocked into Missouri lakes. According to S. Hood, retired hatchery manager with the Pennsylvania Fish Commission, the reservoir was stocked soon after

impoundment with fry and fingerling muskie from Chautauqua Lake, New York and a few years later, adult muskie from Lake Erie were stocked.

Hatchery workers at Linesville occasionally mixed gametes from other fish in the Ohio River basin with those from Lake Pymatuning (S. Hood, personal communication). Therefore, muskie produced at the Linesville Fish Culture Station contained an ever-changing mixture of very different genes from Chautauqua Lake and Ohio River basin waters with an already mixed stock in Lake Pymatuning.

Muskie Genetics

There is evidence to suggest that distinct genetic stocks of muskie exist in North America. Koppelman and Phillip (1986) assessed the level of genetic variability among muskie populations from a variety of locations, including fish from the Linesville Fish Culture Station at Linesville, Pennsylvania and fish from the Chautauqua Fish Hatchery in Mayville, New York. Vertical starch gel electrophoresis conducted on various tissue proteins to determine genotypes at 57 loci revealed that allele frequencies varied substantially among populations. Among the nine populations tested, the Linesville and Chautauqua hatchery collections were most similar to each other, confirming what we have learned about the history of fish exchange between those facilities. Offspring of the Linesville and Chautauqua broodstocks had among the highest genetic variability in those populations.

Subsequent work by Jeff Koppelman (unpublished data) in Missouri revealed that 1983-year-class fish from Hazel Creek Lake exhibited enough genetic variability to cause suspicion of mixed-stock origin. This not only further confirms what we know about fish from Linesville, but it suggests that 1983-year-class muskie from Hazel Creek Lake would be good broodstock not only because of their proven performance, but also because of their genetic variability.

Phenotypic variation at five loci contributed substantially to the amount of genetic differentiation revealed among the populations tested by Koppelman and Phillip (1986). Subsequent work by Jeff Koppelman (unpublished data) revealed that there is an almost-complete difference at the Gpi-B locus between adult muskie from Missouri lakes (which were almost identical) and offspring from Leech Lake broodstock. Szendrey et al. (1992) also found evidence of geographic stock differences in allele frequencies at the Gpi-B locus. Therefore, the Gpi-B locus may be useful as a genetic marker for purposes of distinguishing the Leech Lake stock from others in Missouri, especially since it can be detected easily in fin tissue.

Muskie Thermal Limits, Preferenda, and Optima

We are unaware of a published upper incipient lethal temperature for muskie, but Scott and Crossman (1973) believed that water temperatures as high as 90 F could be tolerated for at least a short period of time. Beggs et al. (1980) reported that muskie occur in habitats which regularly reach maximum temperatures of 86 F in August. Based upon field observations, Oehmcke et al. (1958) speculated that feeding activity may be reduced at water temperatures above 85 F. In Moose Lake, Wisconsin, tagged adult muskie were never observed in water less than 70 F in mid summer (Dombeck 1979). In West Okoboji Lake, Iowa, tagged adult muskie spent most of their late summer at water temperatures a couple degrees warmer than average mid-lake surface temperatures of 73 to 77 F (Miller and Menzel 1986). Minor and Crossman (1978) found that

tagged male muskie chose to stay in shallow water (four feet) during mid summer at temperatures exceeding 83 F.

Szendrey et al. (1992) compared food consumption and relative growth rates among yearling muskie from four geographic stocks at five temperatures (41, 50, 59, 77, and 81.5 F). Food consumption and growth rates were greatest for all stocks at 77 F. This corresponds well with the experimentally determined preferendum of 77 F reported for juvenile muskie by Reynolds and Casterlin (1979). At temperatures of 77 F and lower, yearling muskie from Chautauqua Lake (what we consider to be *E. ohioensis*) did not perform differently than other stocks. However, at 81.5 F, Chautauqua Lake yearlings grew slower than yearlings from other stocks (Leech Lake Minnesota, Wisconsin hatchery system, and an Ohio impoundment). The difference in relative growth rate was statistically significant between Chautauqua Lake yearlings and those from Wisconsin and the Ohio impoundment. Yearlings from the Ohio impoundment were not "Chautauqua" fish (D. Clapp, personal communication). They were most likely *E. masquinongy*, which are the predominant form of muskie in the Ohio River basin.

Reproduction

Little is known about the reproductive biology or behavior of muskie in Missouri. Muskie have been captured in spawning aggregations in both Pomme de Terre and Hazel Creek lakes, but natural recruitment has not been documented in either impoundment. Young muskie experienced significant predatory mortality by largemouth bass in Ohio (Wahl and Stein 1989a) and Illinois (Szendrey et al. 1992). Even in habitats conducive to muskie reproduction and recruitment, typical population densities of largemouth bass and other centrarchids in Missouri impoundments are probably too high to allow survival of naturally produced muskie to age 1.

Growth

Young muskie have always grown well at Pomme de Terre Lake where they typically achieve a mean length of 30 inches by age-3 (Belusz 1978). This is similar to average growth observed in Cave Run Lake (Axon 1981) and Green River Lake (Kinman 1989) in Kentucky. Sexual dimorphism in growth is widely acknowledged (Scott and Crossman 1973); and it has been documented specifically for the significant progenitors of our stock from Chautauqua Lake (Bimber 1982). But we are unaware of any case in which the result of sexually dimorphic growth has been displayed so dramatically as at Hazel Creek Lake in 1992. That spring, when the only adult year class in the lake was age-9, there was virtually no overlap in the length-frequency distributions of males (mean length 36 inches) and females (mean length 42 inches).

Total Mortality

In reviewing the literature on muskie population dynamics in the United States, we could find only five relatively recent estimates of total mortality rate. In three natural lakes managed under 30-inch minimum length limit (MLL) in the northern part of muskie range, mean multi-year estimates of annual adult mortality ranged from 30 to 35% (males in Chautauqua Lake, New York, Bimber 1982; both sexes in Lac Court Oreilles, Wisconsin, Lyons and Margenau 1986; and both sexes in Spirit Lake, Iowa, Christianson 1991). Annual mortality was only 15% for adult females in Lake Chautauqua. Mortality was much higher in two reservoirs in the southern part of muskie range. Day and Stevenson (1989) reported pooled annual mortality estimates of

64% for males (ages three to eight) and 47% for females (ages four through 10) in Clear Fork Reservoir, Ohio, where there was no MLL. Axon (1981) reported a high annual adult mortality of 78% in Cave Run Lake, Kentucky, where there was a 30-inch MLL.

A Schnabel population estimate made in Hazel Creek Lake in 1992 revealed the presence of 413 age-9 male muskie (95% CI: 287 to 679) (D. Neverman, MDC, unpublished data). Assuming that half of the original 1500 fish stocked in fall 1983 were males, the instantaneous rate of mortality of angled but sub-legal male muskie was only 7.2% annually (95% CI: 1.2% to 11.3%) from 1984 through 1991. The extremely low annual mortality rate of 7.2% for male muskie at Hazel Creek Lake suggests that northern Missouri's relatively southern latitude and reservoir environments are not inherently limiting to muskie survival. Prior to our experience with Hazel Creek Lake, the lowest total mortality rates documented in North America were 15% for female muskie at Chautauqua Lake, New York (Bimber 1982) and 15% for age-4-and-older muskie at a sanctuary lake in Ontario (Muir 1964).

Emigration

There has been no attempt to document muskie emigration rate in Missouri, largely because we have had no reason to suspect significant losses at existing muskie lakes. In the last 18 years, only four muskie have been reported in the Pomme de Terre River downstream of the reservoir (R. Dent, MDC, personal communication). At Pomme de Terre, flows up to 120 cubic feet per second are released through a surface tube; all higher releases occur through the main gate at a depth of 85 feet. Hazel Creek Lake also has a well-managed watershed with a relatively low watershed ratio (10:1); the concrete drop-outlet tower lacks a fish barrier, but it may be less attractive to potential emigrants than a typical surface spillway. However, after an 8-inch rain event in May, 2002, four muskie were found dead below Hazel Creek Lake. On May 13, 2001, a 6-inch rain event resulted in considerable emigration of muskie and grass carp out of Henry Sever Lake.

Day and Stevenson (1989) documented muskie emigration in Ohio in the tail-water of 1,000-acre Clear Fork Reservoir from 1983 through 1988. Most emigration occurred when reservoir water level approached or exceeded 12 inches above the level of the surface spillway. This strongly suggests that emigration could be a major factor in loss of muskie from any Missouri impoundment with either a high watershed ratio or a typical surface spillway with no fish barrier. Substantial escapement over a surface spillway was reported for stocked muskie in Murphy Flowage, Wisconsin (Margenau and Snow 1984).

Short-Term Mortality of Stocked Fingerlings

Belusz (1975, 1978) found that mortality of 9 to 11 inches fingerling muskie two to four days after stocking into isolation coves at Pomme de Terre Lake was virtually nil in five years out of six. The exception was 1975 when stocked fingerlings developed disease symptoms 24 hours after release, then 53% died within four days. Serns and Andrews (1986) reported that mortality was negligible for various sizes of fingerlings held in cages for 48 hours prior to their release into four Wisconsin lakes. In holding experiments conducted for 72 hours, Day and Stevenson (1989) measured mortality rates of only 0 to 10% for advanced fingerlings later released into Clear Fork Reservoir, Ohio during 1983 to 1987. Despite documentation of acidosis in stressed muskie by Miles et al. (1974), Mather and Wahl (1989) found that stress-related mortality of

stocked fingerlings could be kept low by minimizing confinement, handling, and abrupt temperature changes. Low mortality of muskie stocked into Hazel Creek Lake in 1983 supports this conclusion. In summary, there is little reason to believe that mortality of muskie fingerlings within the first few days of fall stocking in Missouri is routinely or significantly caused by the stresses of confinement and handling during transportation.

High mortality of stocked muskie fingerlings beyond the first few days has been well documented in Wisconsin (Johnson 1978; Hanson 1986; Serns and Andrews 1986; Margenau 1992), where mortality averaged 61% by late fall in the year of stocking for fingerlings of various sizes (Hanson 1986). At Clear Fork Reservoir, Ohio between 1983 and 1987, estimated mortality of advanced pond-reared fingerlings averaged 36% within 24 to 38 days of stocking in late summer/early fall and 43% by the following spring (Day and Stevenson 1989).

There is increasing evidence that post-stocking mortality of Esocid fingerlings is due primarily to predation. Carline et al. (1986) documented total mortality rates averaging 70% for tiger muskie fingerlings within 50 days of stocking into Ohio impoundments. Short-term mortality attributable to predation by largemouth bass averaged 30%. But virtually all predatory mortality occurred when hybrids were stocked at lengths under 8 inches—much smaller than the fish we typically stock in Missouri. Wahl and Stein (1989a) stocked ten muskie per acre at average sizes of 5.7, 7.1, and 8.1 inches into three small impoundments in Ohio which contained 5 to 15 stock-size ($\geq$ 8 inches) largemouth bass per acre. On average, 12% of the muskie were consumed by largemouth bass; but only 2% of those stocked at 8.1 inches were eaten. Muskie consumed by largemouth bass were usually 40 to 65% of bass total length. Predatory losses were not significantly associated with bass density. Most predatory mortality occurred within the first few days of stocking.

The high approachability of fingerling muskie immediately after stocking suggests that they may be particularly vulnerable to predation for a day or two while they adjust to their new environment. They may also be quite vulnerable as they disperse to preferred habitats (dense macrophytes or flooded terrestrial vegetation at depths less than 10 feet), after which they seem much more evasive (Belusz 1975; Hanson and Margenau 1992). The presence of aquatic vegetation during dispersal may be important because largemouth bass predatory efficiency decreases as plant density increases (Savino and Stein 1982).

Research conducted outside Ohio also suggests that a significant positive association exists between short-term fingerling survival and length at stocking (Kinman 1989; Margenau 1992). In Green River Lake, Kentucky, post-stocking electrofishing CPUE of primarily young-of-year and yearling muskie was four times higher for fingerlings stocked at 12 to 14 inches than for those stocked at 8 to 10 inches (Kinman 1989). In Wisconsin, length at stocking seemed to influence post-stocking survival most during the fall months; size-dependent survival was not detectable during winter when predators were inactive (Margenau 1992).

Indirect evidence suggests that predation by large Esocids, including adult muskie, may influence the post-stocking survival of fingerling muskie (Serns and Andrews 1986; Margenau 1992). High post-stocking mortality of 13.5-inch fingerlings occurred in the presence of a relatively dense population of 0.7 resident muskie per acre (20 inches) in English Lake, Wisconsin (Margenau 1992).

Angling Effort and Success

Approximately 78% of all muskie fishing trips at Pomme de Terre are made by non-local anglers, most from the St. Louis, Kansas City, and Springfield areas (Belusz and Witter 1986). Angling effort for muskie increased from one to two hours per acre per year in the mid 1970s to three to five hours per acre per year in the mid-1980s, where it remains today. In comparison, muskie fishing pressure averaged 15 hours per acre per year (range four to 29) in eight northern Wisconsin lakes (Hanson 1986).

Mean angler catch rates increased from one legal-size muskie (> 30 inches) per 108 hours during 1976 to 1977 to one legal fish per 39 hours during 1978 to 1982. This increase was associated with increased stocking densities starting in 1976. There was a mid 1980s slump in mean catch rate to one legal fish per 61 hours (1983 to 1987), probably resulting from low stocking densities in 1980 and 1981. From 1988 through 1992, catch rates returned to one legal fish per 39 hours (R. Meade, MDC, unpublished data).

A creel survey was conducted at Hazel Creek Lake from 5/27/89 to 7/22/89 in order to document muskie angling participation and success five years after introduction, and to gage angler attitudes toward muskie. In 25 of 501 documented trips (5%), anglers fished specifically for muskie and caught sub-legal-size fish (< 42 inches) at a very high average rate of one fish every seven hours. Most muskie anglers at that time were local Missourians (85%) whose estimated trip expenses averaged $29.77, similar to the $23.81 spent per day by muskie anglers in Minnesota (Younk and Cook 1992). When 290 lake anglers interviewed for the first time were asked, "Do you feel that the muskie should be restocked in the future?", 70% said yes, 5% said no, and 25% (mostly ictalurid anglers) had no opinion (Neverman 1990).

Catch-and-Release

Under experimental conditions, release survival of angler-caught muskie has been relatively high. Strand (1986) reported 100% survival for 14 adult muskie which were caught by anglers in 3- to 4-minute struggles during mid-summer, anesthetized, and surgically implanted with radio transmitters before release. Beggs et al. (1980) angled 25 muskie in four-minute struggles during mid-summer, anesthetized them, and then cannulated them in respirometers while conducting blood tests. Total handling time ranged from 11 to 35 minutes per fish, and holding for recovery lasted up to 84 hours. Mortality under these conditions was 30%. The cause of death was not identified, but blood lactate levels were not as high as those characterizing fatigue in most other species. Fish recovered from acidosis in 12 to 18 hours. After their release, 73% of the fish which survived cannulation and confinement were recaptured in the wild up to a year later, indicating high survival of released fish.

Summarizing cooperative tagging studies among various state agencies and members of Muskies, Inc., Richards and Ramsell (1986) reported that approximately 17% of 1,600 angler-tagged muskie were recaptured by anglers. The recapture rate of 578 muskie caught, tagged and released by 16 experienced anglers, averaged 28% (range 22 to 44%). These studies proved that angler-caught and released muskie could survive and contribute to the future quality of muskie fishing.

According to Muskies, Inc. records, from 1970 to 1975, members released 19% of the legal muskie they caught in 1970, 59% in 1972, and 85% in 1975 (Davis 1983). A similar time frame for acceptance of catch-and-release fishing was documented at Pomme de Terre Lake. Catch records at the State Park Marina indicated a 36% legal release rate in 1978; this increased to 54% in 1980 and 89% in 1982 (Dent 1986). Show-Me Muskie Project results indicate that Missouri muskie anglers rarely harvest muskie.

In waters where muskie are newly introduced and subjected to fishing pressure by novice local anglers, high exploitation could occur until these anglers start voluntarily releasing a high proportion of legal muskie. Problems could be exacerbated if anglers primarily pursuing other species experience high incidental catch rates and decide to harvest legal muskie.

Muskie Feeding Ecology and Fish Community Interactions

Muskie are known to be effective, but selective, predators. Where gizzard shad are present, they comprise a large proportion of the diets of muskie and tiger muskie of all ages (Carline et al. 1986; Wahl and Stein 1988; Kinman 1989; Szendrey et al. 1992). At Pomme de Terre Lake, muskie consumed gizzard shad, carp, and, in that order (Vasey 1968). Examination of 24 adult muskie stomachs in 1969 and 1979 revealed that gizzard shad and carp were again the predominant food items; they occurred in 85% of the stomachs (R. Meade, MDC, unpublished data).

Laboratory and field studies have shown that muskie selectively consume gizzard shad. Weithman and Anderson (1977) fed 2-inch prey to 13-inch muskie fingerlings in tanks and found that vulnerability to predation was high for gizzard shad and golden shiners, intermediate for bluegill and largemouth bass, and very low for channel catfish. However, these experiments did not control for optimal prey size as described by Gillen et al. (1981), making inferences about natural situations difficult. Wahl and Stein (1988) presented muskie in the laboratory with prey of optimal size (30 to 36% of muskie length for gizzard shad and 30 to 35% for bluegill). Mean captures per strike were significantly higher for gizzard shad (0.78) than for bluegill (0.14), and less time was spent engaging in the energetically costly behaviors of pursuing and following on gizzard shad than on bluegill. Wahl and Stein (1988) recommended that muskie not be stocked into centrarchid-dominated systems, but rather into systems with soft-rayed or fusiform prey.

Young muskie eat brook silversides (Wahl and Stein 1989b; Szendrey et al. 1992). From March through June in Pierce Lake, Illinois, brook silversides occurred more frequently in the stomachs of age-1 muskie than cyprinids, sunfishes, or gizzard shad (Szendrey et al. 1992). Brook silversides were second to gizzard shad in frequency of occurrence during a subsequent sample period when larger muskie sought larger prey (T. Szendrey, unpublished data). The existence of brook silversides in muskie lakes may increase the prey available to stocked fingerlings during a period when they are not yet of optimal length to consume large young-of-year gizzard shad.

We are unaware of any documented accounts of muskie introductions which adversely affected existing fish communities or fisheries. Muskie will eat bluegill when nothing more preferred is available (Krska and Applegate 1982). But several stocking evaluations have shown that neither muskie nor tiger muskie consume enough bluegills to alter bluegill population structure (Snow 1968; Tomcko et al. 1984; Carline et al. 1986; Wahl and Stein 1988; Storck and Newman 1992).

Muskie probably do not consume crappies in significant numbers, especially if gizzard shad are available. We found only one documented report of muskie predation upon crappie—a single 7-inch fish eaten by a 24-inch muskie in Green River Reservoir, Kentucky (Kinman 1989). There is very little documented evidence that muskie eat Ictalurids. Weithman and Anderson (1977) found that Esocids selected strongly against channel catfish as prey. Muskie have not been reported to consume largemouth bass whenever gizzard shad were present or when population density of bass was low or moderate.